

Red Bull's Project Endurance 2.0

Integrative Scientific Strategies For Enhancing Human Athletic Potential

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Purpose: Understanding how elite athletes succeed in their chosen sport is complex. The Red Bull's Project Endurance (RBPE) was designed to discover, via novel technologies & integrative science, the complexity of human performance, with the explicit goal of developing strategies that advance human athletic potential. This year's project tried to determine what effects transcranial magnetic stimulation (TMS) had on neuromuscular fatigue and cycling performance in context to central governor theory principles. This paper highlights how TMS affected cardio-respiratory responses and cycling performance during a 4k time-trial (4kTT) in world-class cyclists during three days of repeated high intensity endurance and isometric force exercises.



Methods: Four world-class athletes attended RBPE in Santa Monica, Ca. Athletes exhibited four cycling phenotypes (BMX sprint cyclist, cyclo-cross bike racer, half-Ironman triathlete, and an extreme ultra-endurance mountain biker). Data collection included TMS, EEG, EMG, motion capture & velocity measures, maximal isometric force, cardio-respiratory function, cardiac impedance measurements, regional near-infrared measured oxygen saturation profiles, cycling performance during a 4k time-trial (4kTT), baseline hydration and segmental lean tissue, 24-hr sensor technologies for assessing blood glucose and stress-recovery heart rate variability measures, morning blood and urine samples, and blood samples before, during, and after key measurement points was also collected.

Results: TMS had a positive effect on decreasing cortical silence periods in each athlete. Athletes with greater cycling endurance demands (triathlete and ultra-endurance cyclist) showed enhanced 4kTT performances with a corresponding increase in isometric max force development. Most interestingly these improvements took place despite each athlete exhibiting one or more of the following: blood markers of fatigue, extreme regional oxygen desaturation ($\leq 20\%$ oxygenate hemoglobin content during 90% of the 4kTT) with corresponding low blood oxygen content, and evidence of moderate/severe respiratory distress (respiration rates exceed 55 bpm). Additionally, as fatigue started taking place in each athlete over repeated work days, cycling performance strategies changed in each cyclist's cadence, gearing, and applied pedal force that either improved or did not improve their respective 4kTT results.

Conclusions: These results indicate that TMS positively improved central brain silent periods. However, resulting 4kTT performance improvements were related to a cyclist's performance phenotype & pedaling stroke force development strategies.

Athlete Biographies



MIKE DAY
(OLYMPIC SILVER MEDALIST)

Is a professional American "Current School" Bicycle Motocross (BMX) racer. On June 14, 2008 Mike Day won a place on the USA BMX Olympic Team by winning the Team Trial at the Olympic Training Center in Chula Vista, California. Mike Day won the Silver medal in the Men's BMX Final at the 2008 Summer Olympic Games.

In addition to his Olympic Medal, Mike's professional career includes the following accomplishments: UCI 2004 Elite Men Silver Medal World Cup Champion; UCI 2005 Elite Men Silver Medal World Cup Champion; UCI 2006 Elite Men Bronze Medal World Cup Champion; UCI 2007 Elite Men Supercross World Cup Champion; 2005 NORA Cup winner; 2008 ABA Golden Crank Pro of the Year; 2005 Elite Men National Elite Champion.



TIM JOHNSON
(CYCLE CROSS)

Is an American professional cyclist who has found success in both cyclocross and road bicycle racing. He is one of only two male riders from the United States to stand on a UCI Cyclocross World Championships podium. Johnson has six career national championships - three Elite, two Espoir and one Junior - and a bronze medal from the UCI Cyclocross World Championships that he won in 1999 in Poprad, Slovakia.

Johnson was arguably 2009's most successful American Cyclocross rider, winning 11 races, including the US Cyclocross National Championships in Bend, Oregon. In 2009, Johnson was first in the North American Cyclocross Trophy overall standings and second in the US Gran Prix of Cyclocross overall standings.



JESSE THOMAS
(WORLD-CLASS TRIATHLETE)

Started in endurance athletics as an Oregon State Track and Cross Country Champion, eventually competing for Stanford University's powerhouse Track & Field and Cross Country Teams. At Stanford, he was a NCAA All-American and School Record Holder in the 3000m Steeplechase. In 2011, he began in pro triathlon career. In May that year, he shocked the triathlon world by winning the prestigious Wildflower Triathlon. He went on to have a solid rookie year including a number of other top 5 finishes. Since his rookie year he has won the following races.

4 Time Wildflower Triathlon Champion: 2011-2014
2012 70.3 Poconos Champion
2012 Rev3 Florida Champion
2012 Rev3 Maine Champion



REBECCA RUSH
(ULTRA-ENDURANCE ATHLETE)

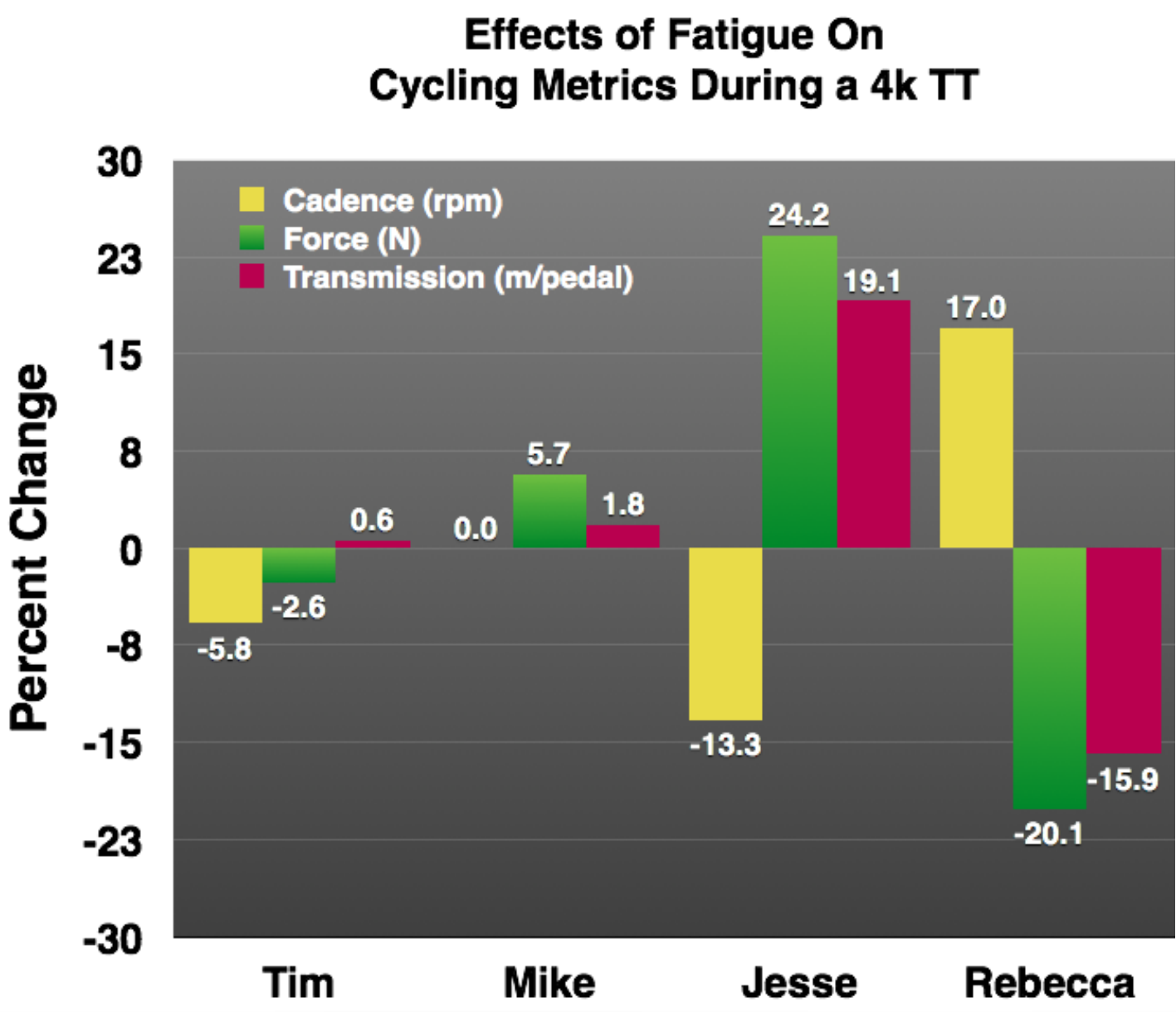
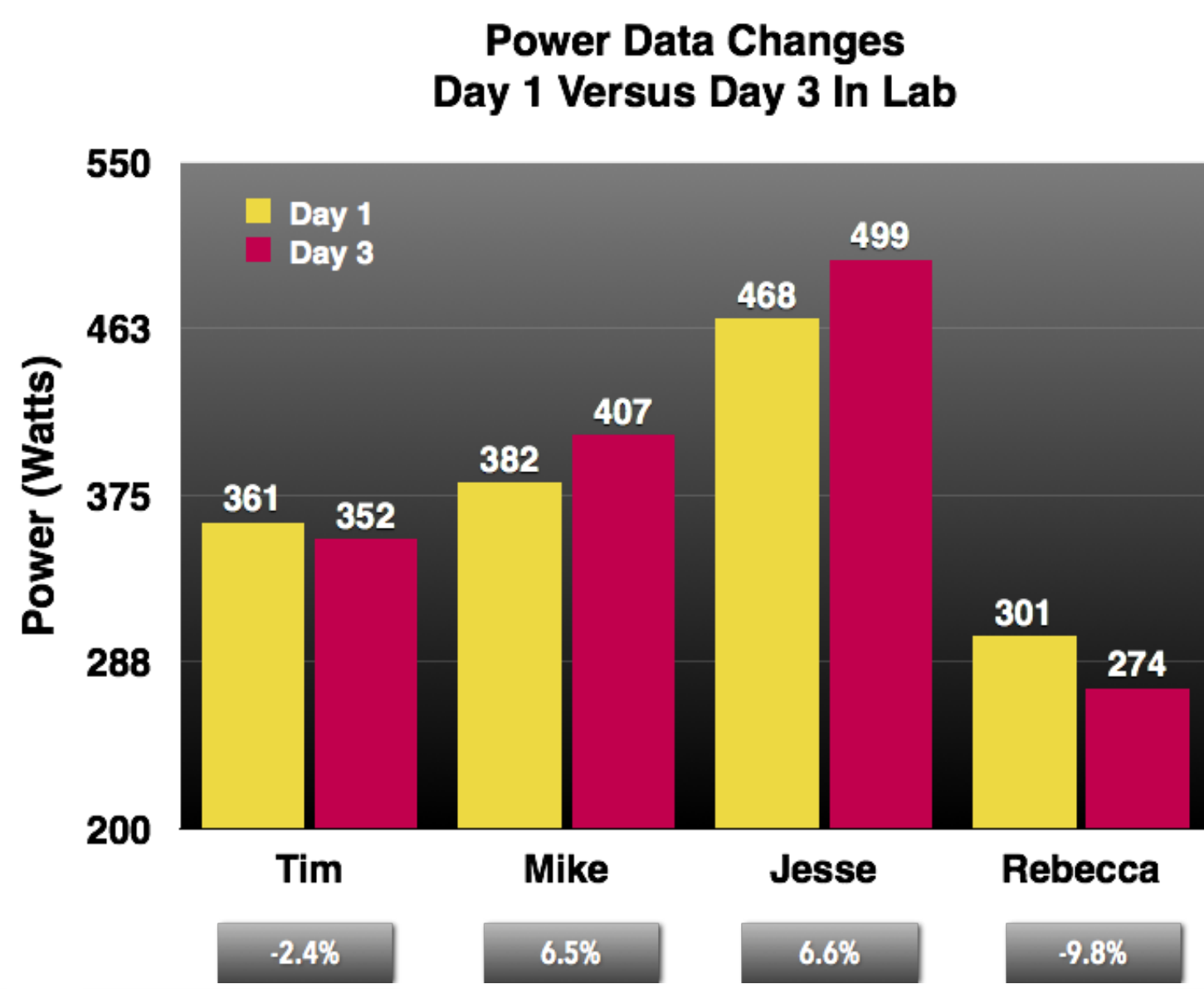
Her national and world titles in whitewater rafting, adventure racing, orienteering, and cross-country skiing certainly impress, but they only set the stage; it's the two-wheeled victories that really lengthen her resume. Rusch's mountain bike accomplishments would strain the pixels on your screen. National wins across multiple off-road formats top the list, as well as record-setting victories at storied ultra endurance races like the Leadville Trail 100, Dirty Kanza 200, and 24 Hour MTB World Championships. Not content to wait for the race to come to her, Rusch also claimed the record on the 142-mile Kokopelli Trail, coming in more than an hour and a half faster than the previous champion. It wasn't her idea, but it doesn't take a professor to see why she earned the moniker "The Queen Of Pain."

4K Time Trial Results

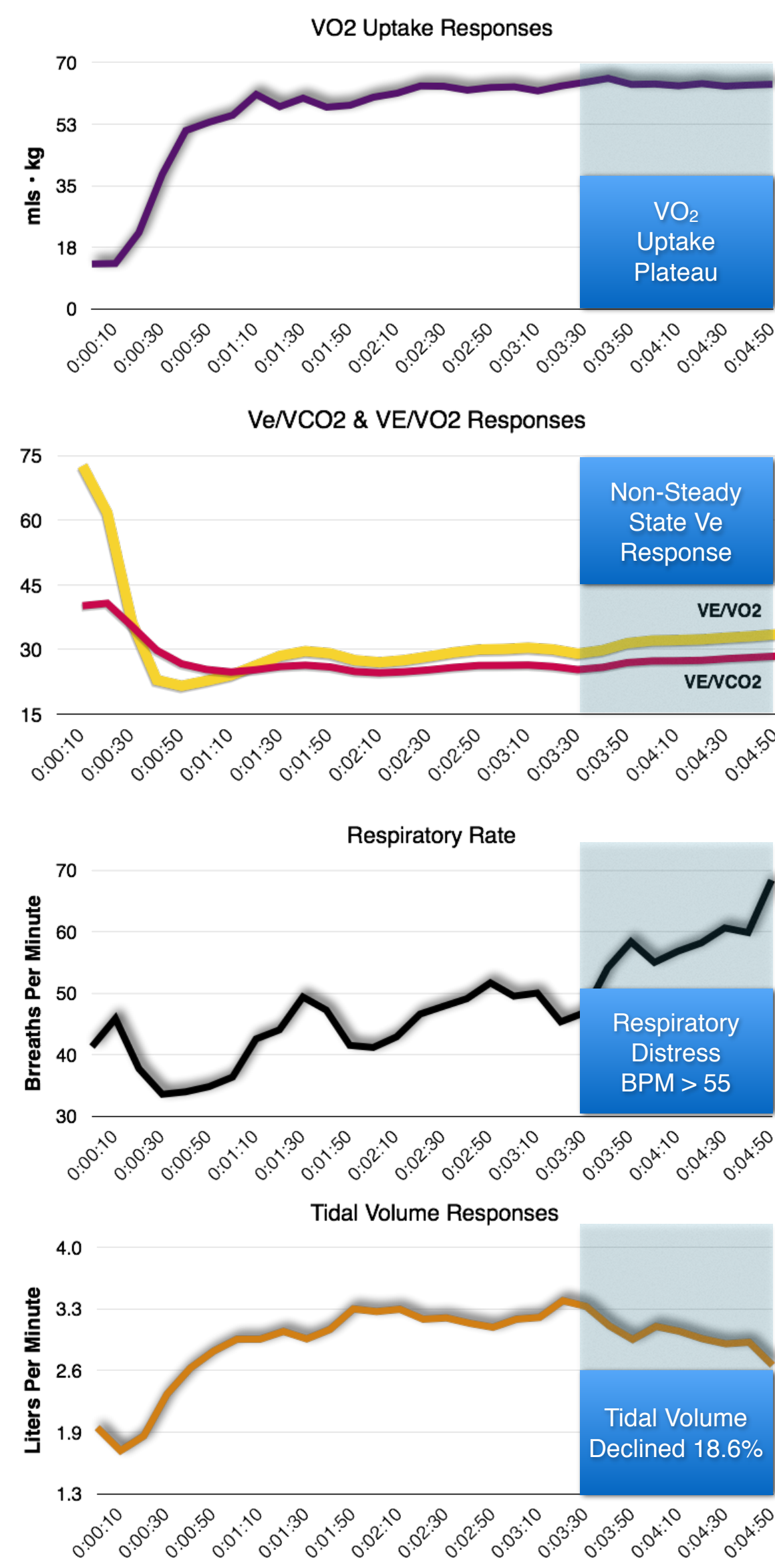
Cyclist	Weight (kg)	HR (BPM)	Power (Watts)	Power (Watts/kg)	VO2 Uptake (mls • kg)	O2 Uptake/Watts (mls • watt)	Pedal Force (N)	Transmission (m/rev)	Cadence (RPM)	Work/HR Beat (J)	Speed (km/h)
Tim	74.0	160	362	4.892	59.5	11.8	199	7.16	99	155	42
Mike	100.2	154	395	3.936	47.0	11.3	181	6.14	118	158	44
Jesse	82.0	165	487	5.936	56.0	9.0	301	8.85	91	211	48
Rebecca	63.8	155	282	4.422	49.7	11.0	165	6.94	97	111	39

Represents the mean of three in-lab 4k TT efforts.

Cycling Performance Changes Following High Intensity Endurance & Isometric Strength Exercise



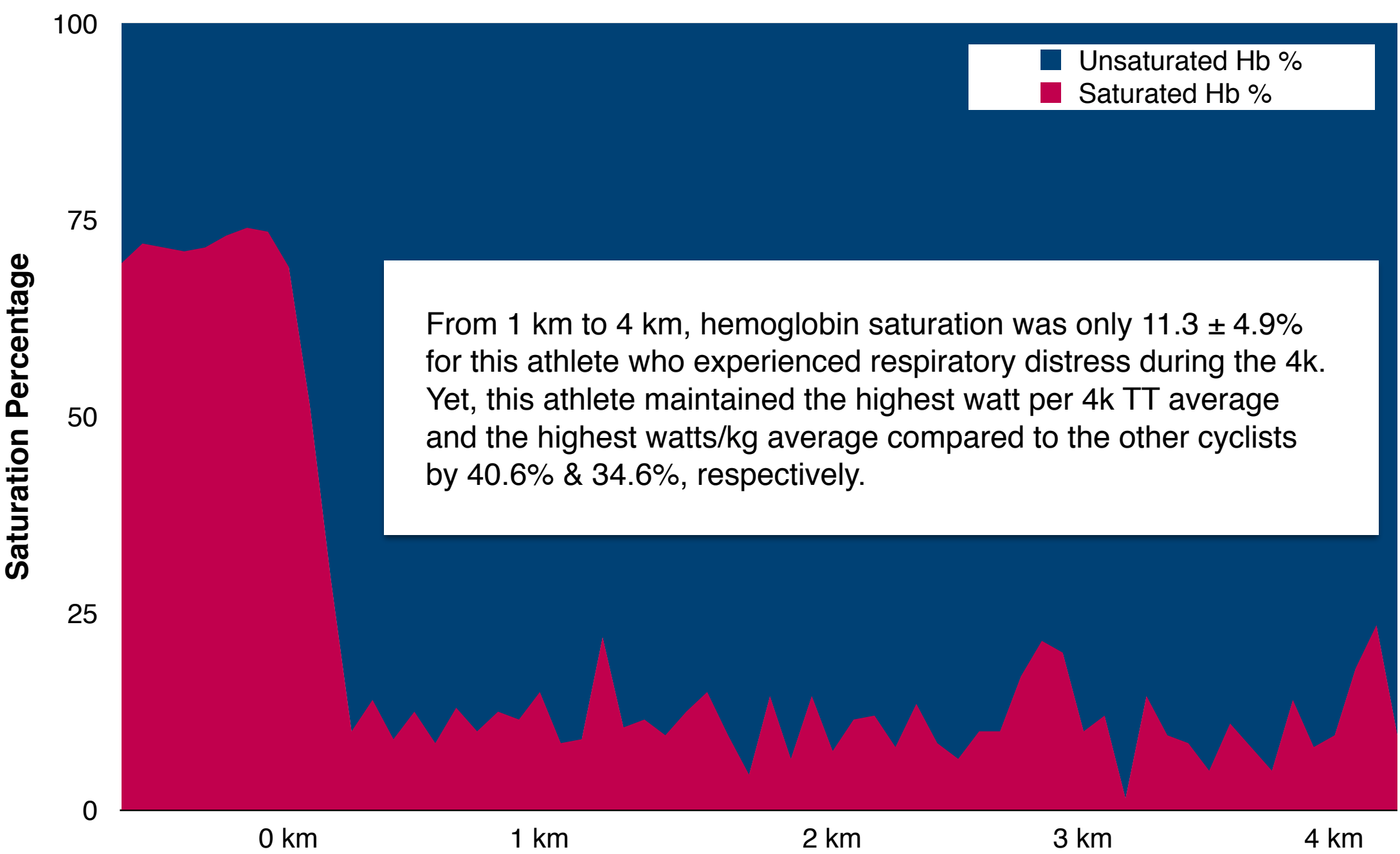
A Sample Integrated Cardio-Respiratory And Cycling Performance Response Profile



Cyclus-2 Data For 4k Time Trial Cycling Performance

KM	Time Splits (Secs.ms)	Heart Rate (BPM)	Power (watts)	Watts/kg	Pedal Force (N)	Cadence (RPM)	Transmission (m/rev)	Speed (km/h)
0-1	74.10	147	525	7.09	300	96	8.52	48.7
1-2	74.60	165	503	6.80	343	81	9.89	48.2
2-3	75.61	170	489	6.61	331	82	9.71	47.5
3-4	75.13	176	489	6.60	339	80	9.97	47.7
Mean	74.86	165	501	6.78	328	85	9.52	48.0

Changes in Skeletal Muscle Hemoglobin Saturation (Mean Values of Left and Right Leg)



Our Testing Set-Up

